Impact of tropical cyclone wind forcing on the global climate in a fully-coupled climate model

Hui Li

Aixue Hu, Gerald Meehl, Nan Rosenbloom, Gary Strand

CGD, NCAR

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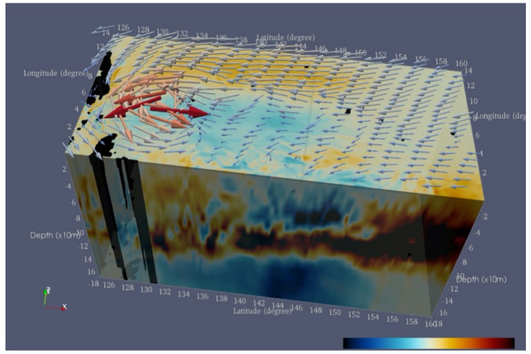

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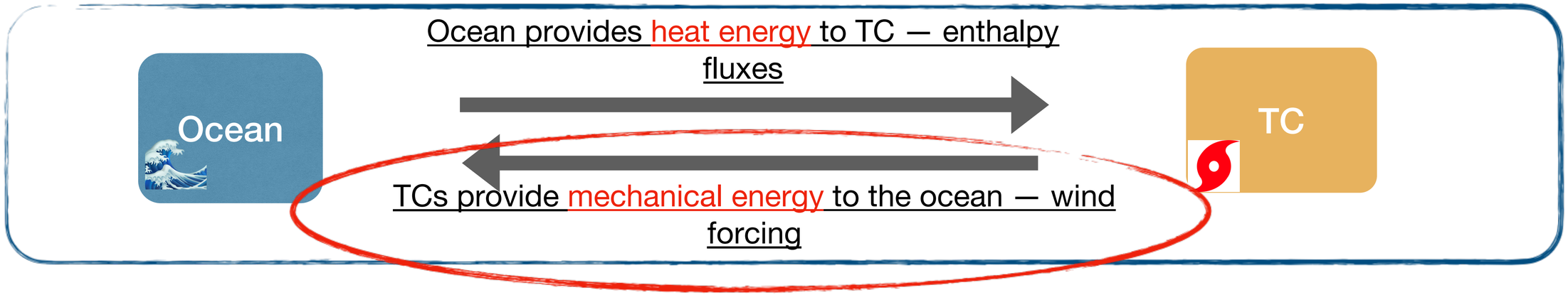
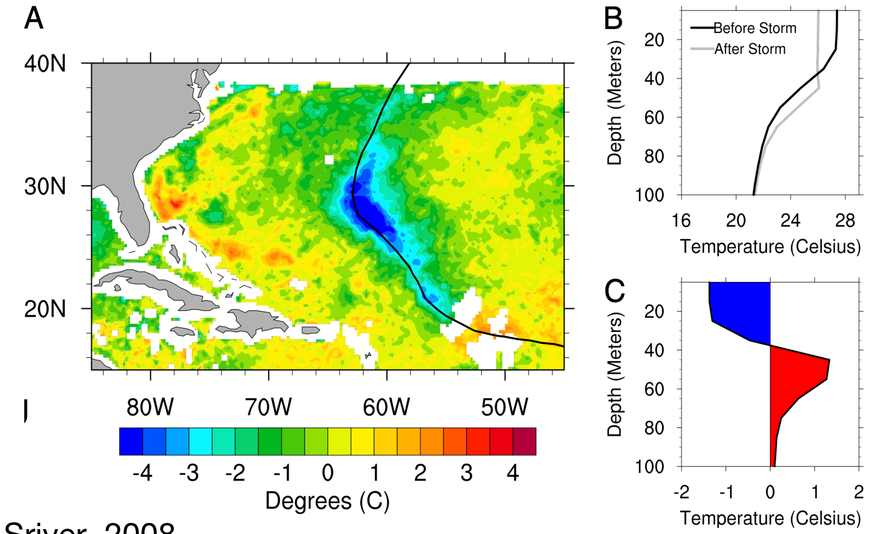
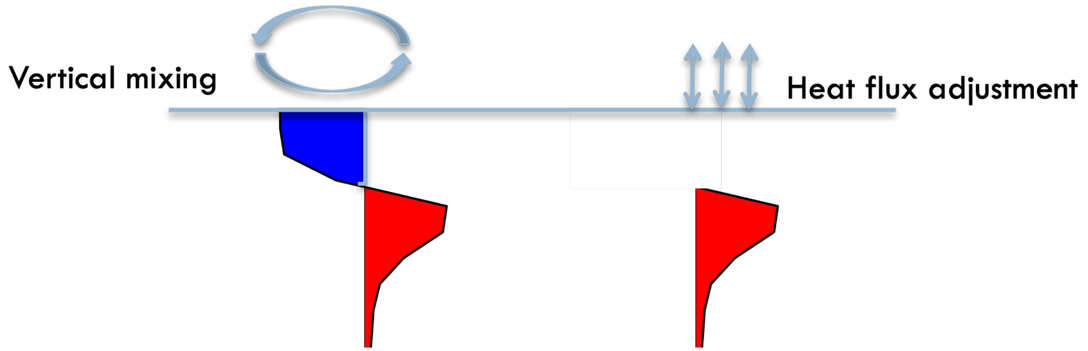
Tropical cyclone (TC) - ocean interaction and the impact on the climate





Sriver, 2008

❖Turbulent ocean vertical mixing → net heat gain in the ocean



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TCs' impact on climate

- TCs have the potential to alter ocean heat content and heat transports [*Emanuel, 2001; Srive and Huber, 2007; Hu and Meehl, 2009; Fedorov et al., 2010; Mei et al., 2013*], ocean temperature patterns, seasonal cycles of SST and mixed layer depth. [*Vincent et al., 2014; Hart 2011; Li and Sriver, 2018*]

- Understanding TCs' contribution to the climate system may help constrain uncertainties in climate simulations and projections.
- To understand the impact of TCs within the coupled climate system, where the ocean's responses to TCs can also feedback to the atmosphere and subsequently affect climate mean state and variability, we will need to have a fully coupled global experiment.

Here we investigate the ocean's response to TC forcing and its feedback to the atmosphere in a fully-coupled global climate model.

Method -- TCs in CESM

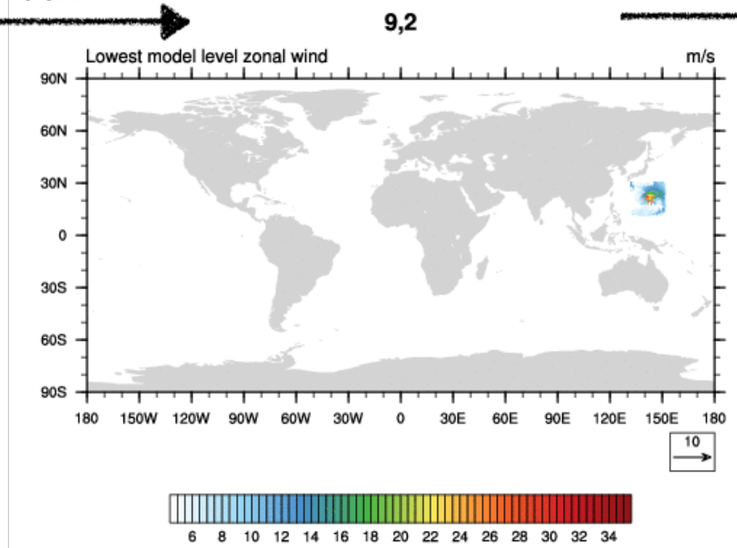
- Add transient TC surface winds from the high-res (0.25° atmosphere) model to the low-res coupled model (1° atmosphere & 1° ocean)

HR-cntl

Atmosphere CAM5 SE 0.25° grid

Ocean POP2 1° grid

Take snapshots TC winds within a 20°x20° domain box

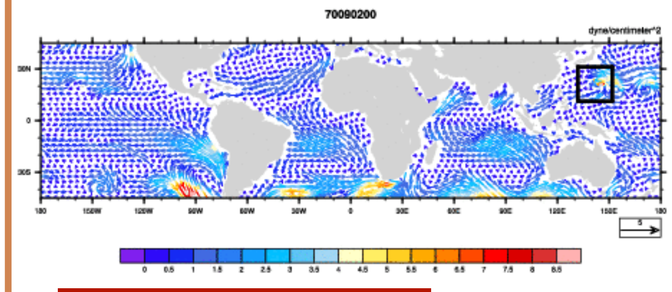


Add the TC snapshots into the low-res model

LR-cntl

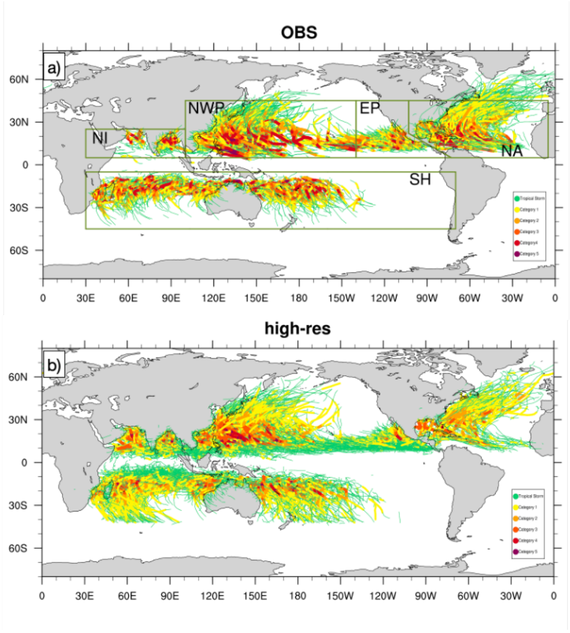
Atmosphere CAM5 SE 1° grid

Ocean POP2 1° grid



LR-TC

100 years



Diagnose the impact of TC wind forcing within the coupled climate system
by comparing LR-cntl and LR-TC

Results

- Composite responses in the ocean and atmosphere

- Impact of TC winds on the large-scale climate mean state
  - Ocean heat content, SST, surface fluxes and precipitation
  - Ocean temperature response to TC forcing
  - Ocean circulation and heat transport
  - Impact on climate variability

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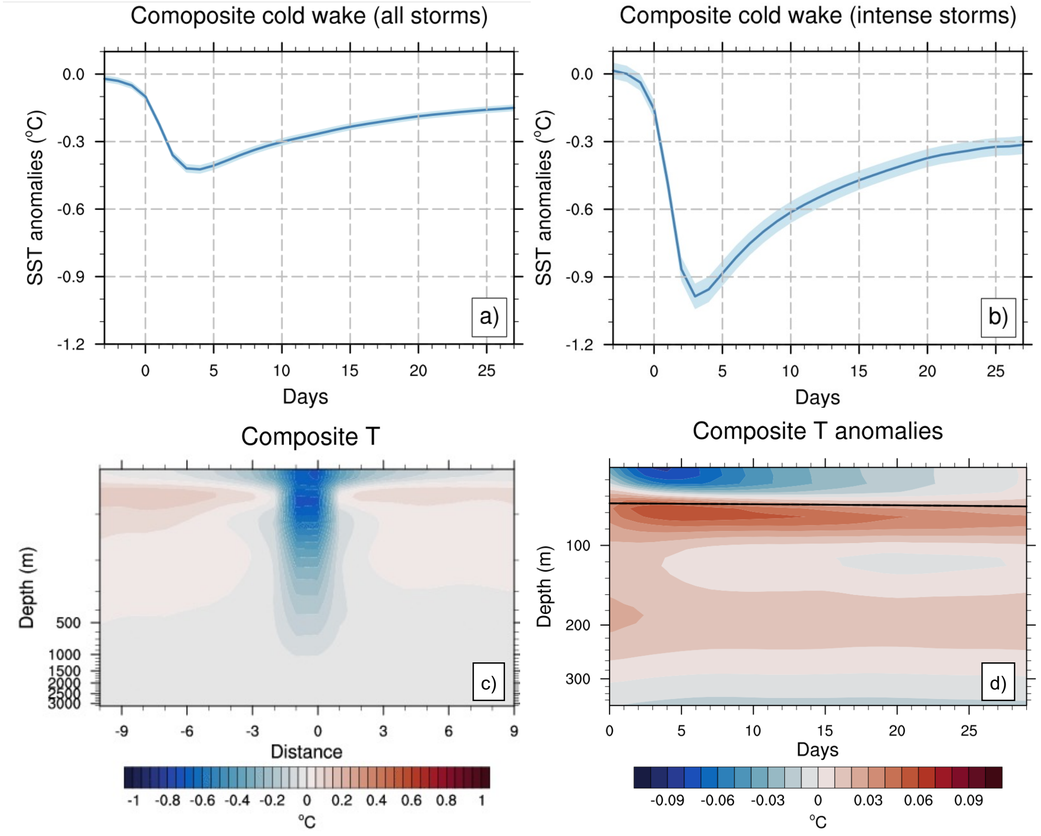
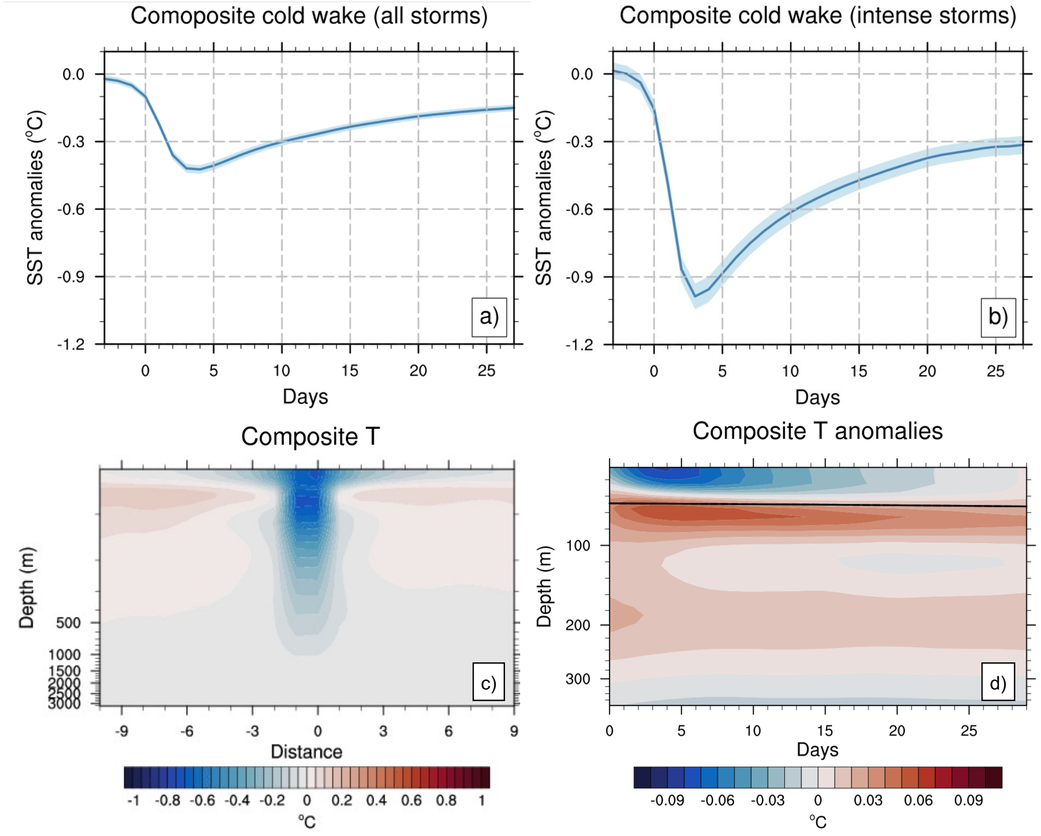
Composite responses

SST and ocean temperature



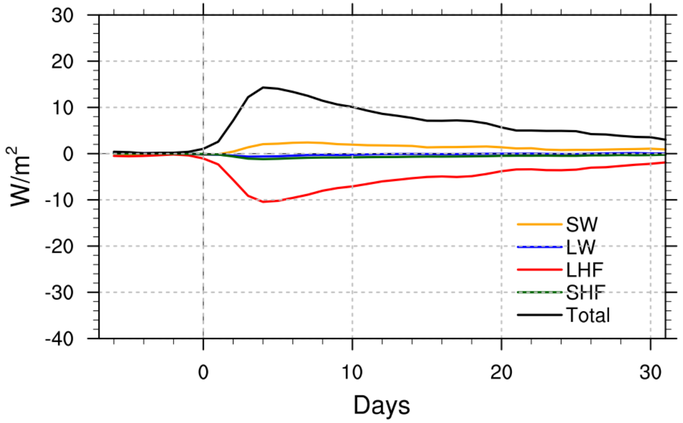
Composite responses

SST and ocean temperature



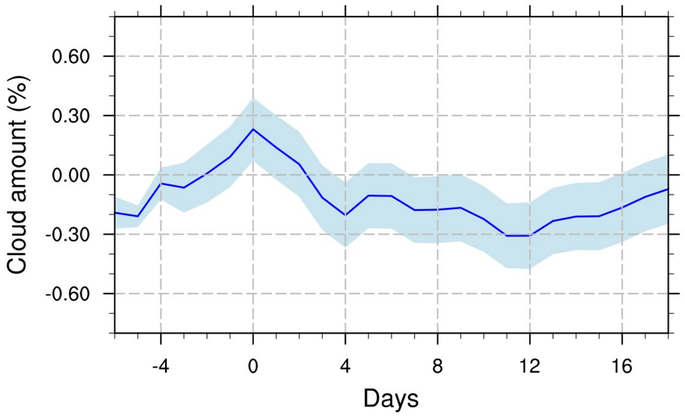
Surface heat fluxes

Q = SW - LW - LHF - SHF



cloud

Low cloud amount anomalies



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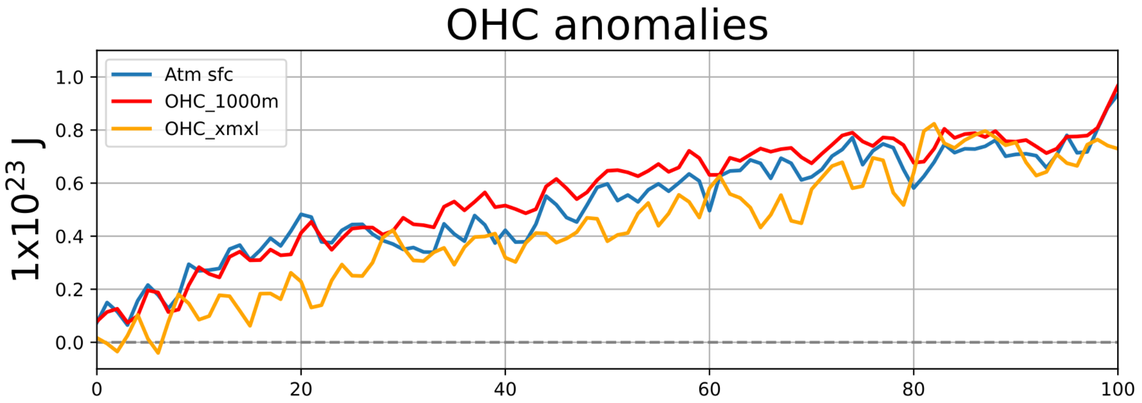
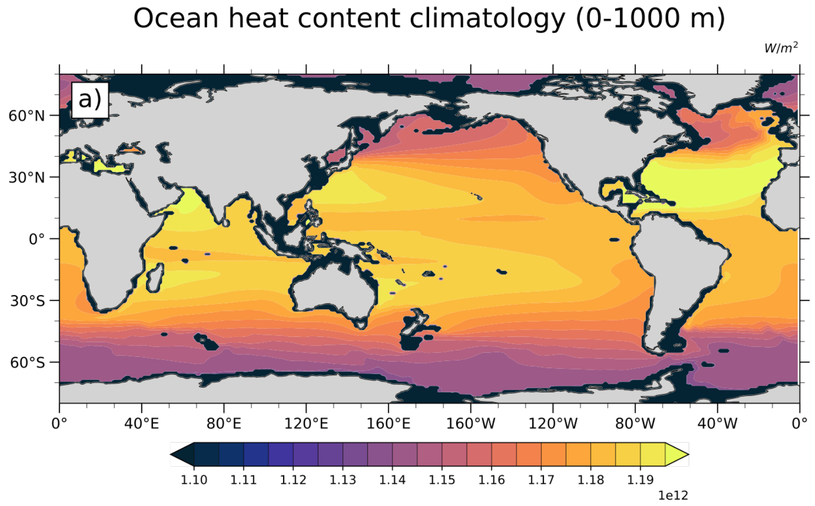
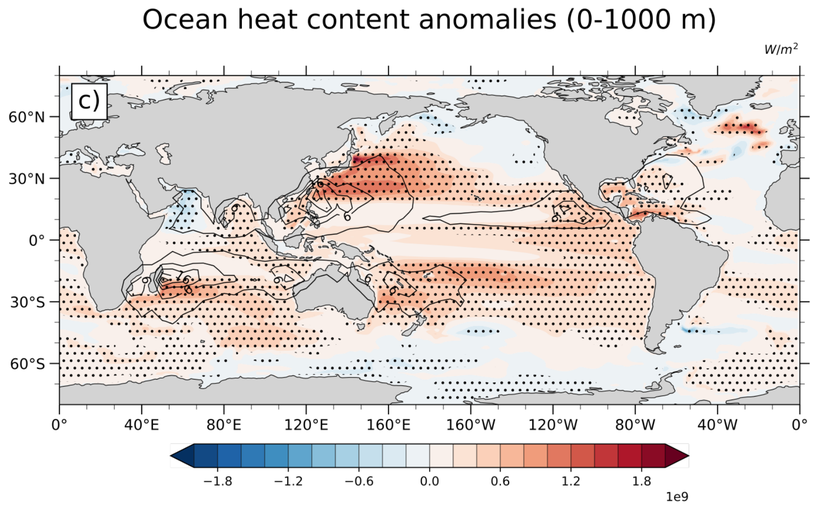
Ocean heat content







- Average heat uptake of $1x10^{21}$ J per year, an annual heating rate of 0.03 PW.
- OHC is almost entirely attributable to the total surface heat flux anomalies. Radiative heating is the dominant factor, and the LHF is a major counteractive term.

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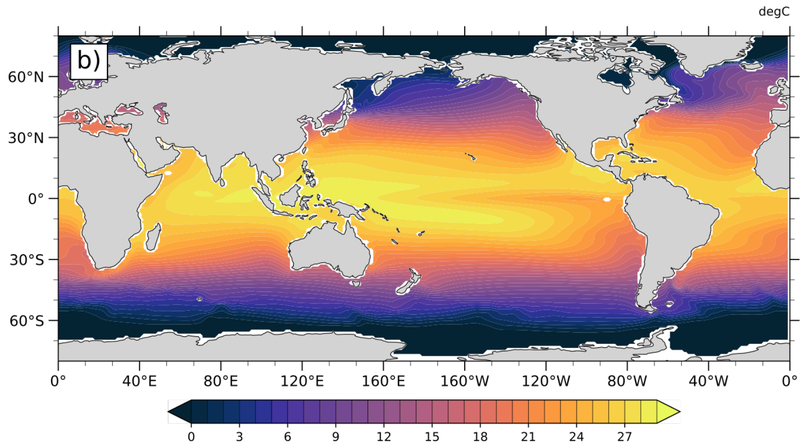
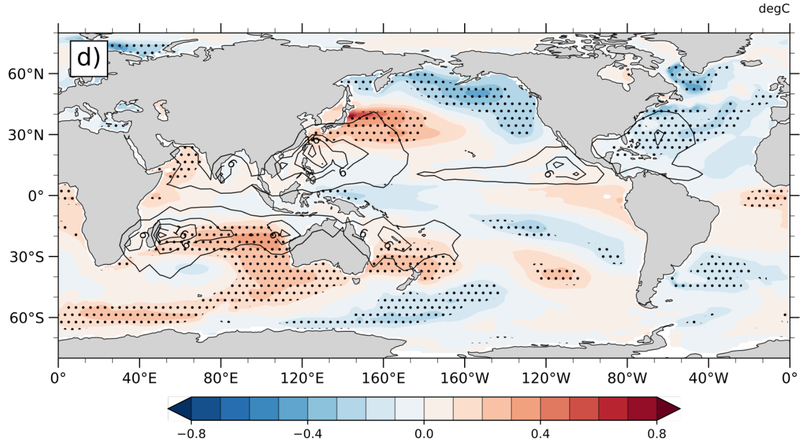
Impact on SST, heat fluxes and precipitation

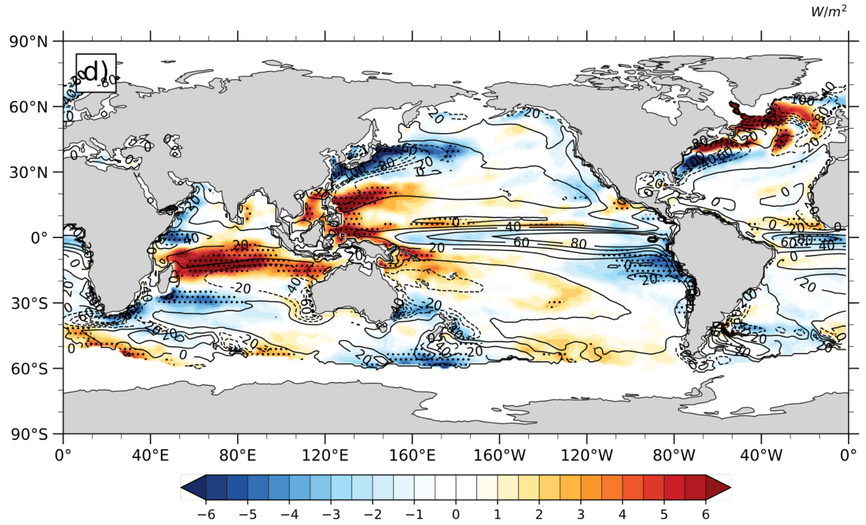
SST climatology



SST anomalies

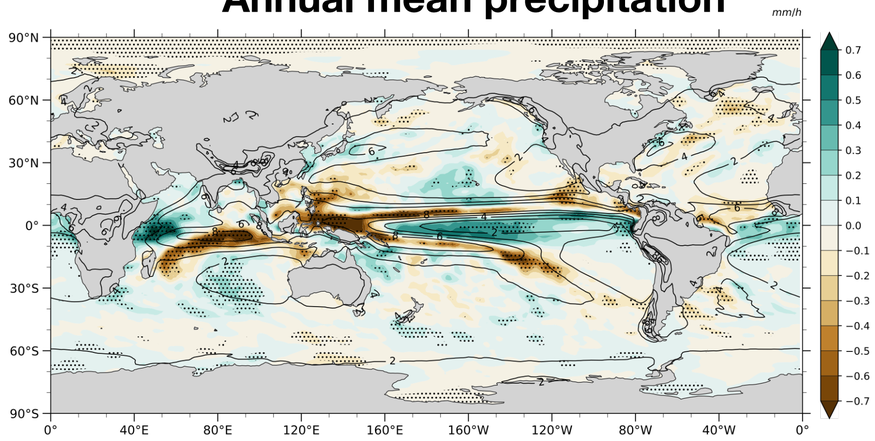


Total heat flux anomalies

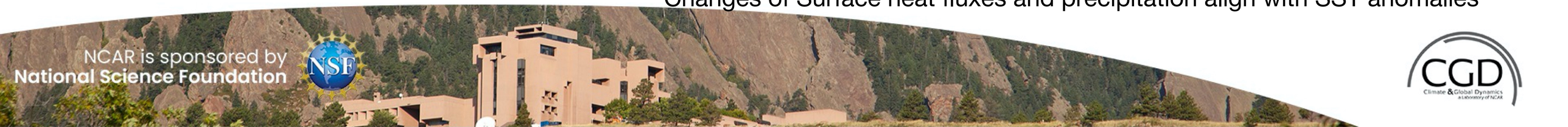


*Positive into the ocean

Annual mean precipitation



- Changes of Surface heat fluxes and precipitation align with SST anomalies



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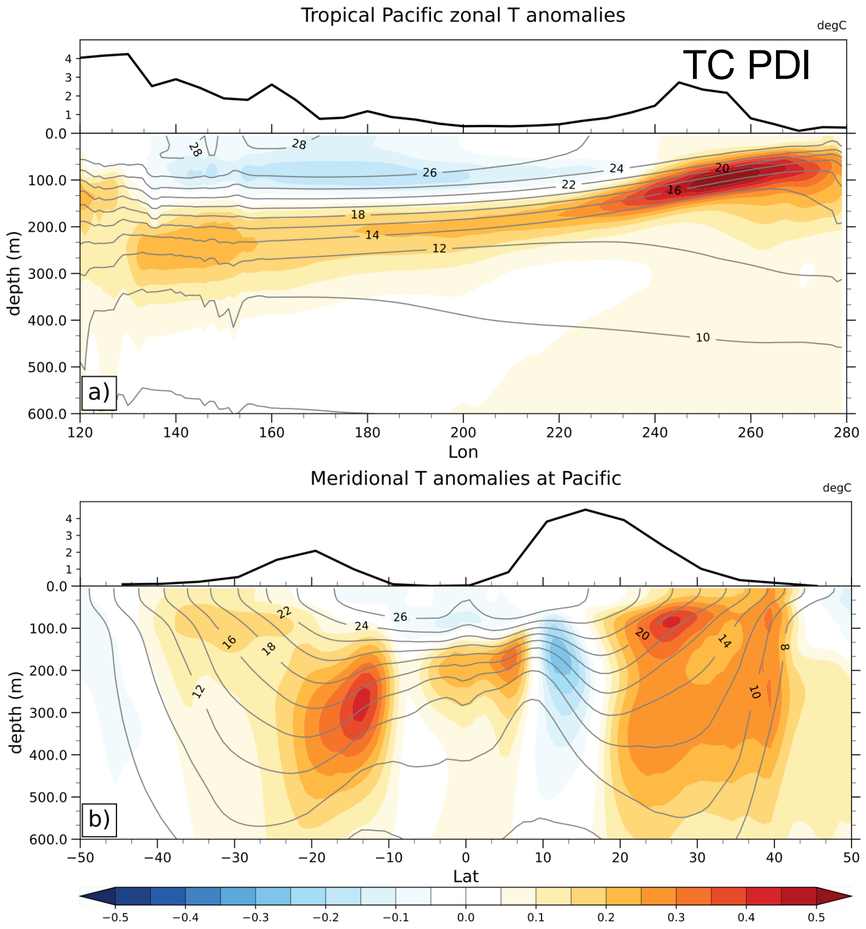
Impact on ocean temperature



- TC-induced warm anomalies enters the equatorial main thermocline, gets carried eastward by equatorial Kelvin waves and the Equatorial Undercurrent, and accumulates and rises to the surface in the eastern Pacific.

- The warm anomalies in the permanent thermocline are transported equatorward along the isotherms through the subtropical cells (STCs)

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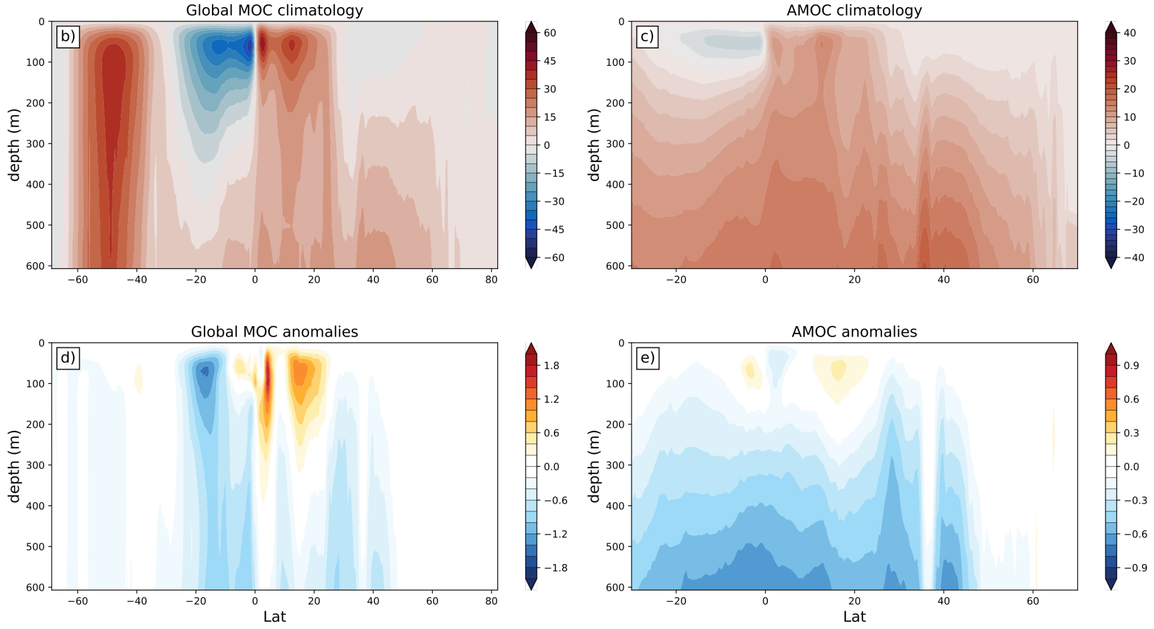
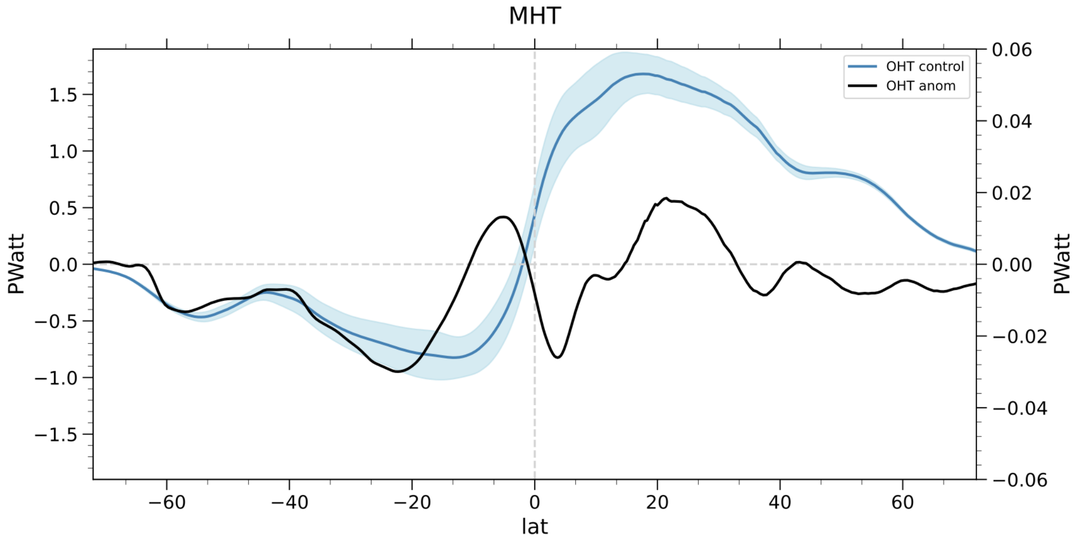
Impact on ocean circulations and meridional heat transport





- Strengthened STC at TC wind bands
- Weakened AMOC
  - due to increased heat and freshwater flux

- Increased poleward heat transport at the subtropics
- Heat convergence in the deep tropics

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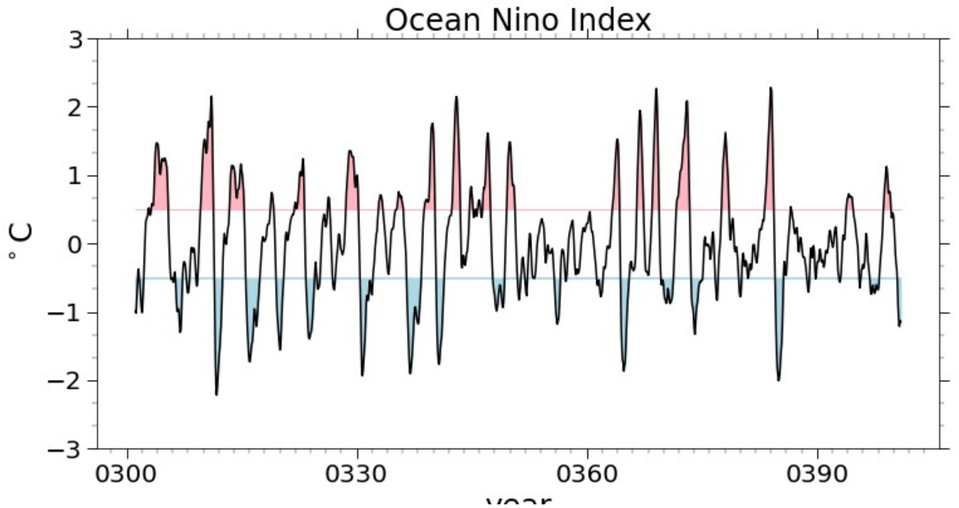
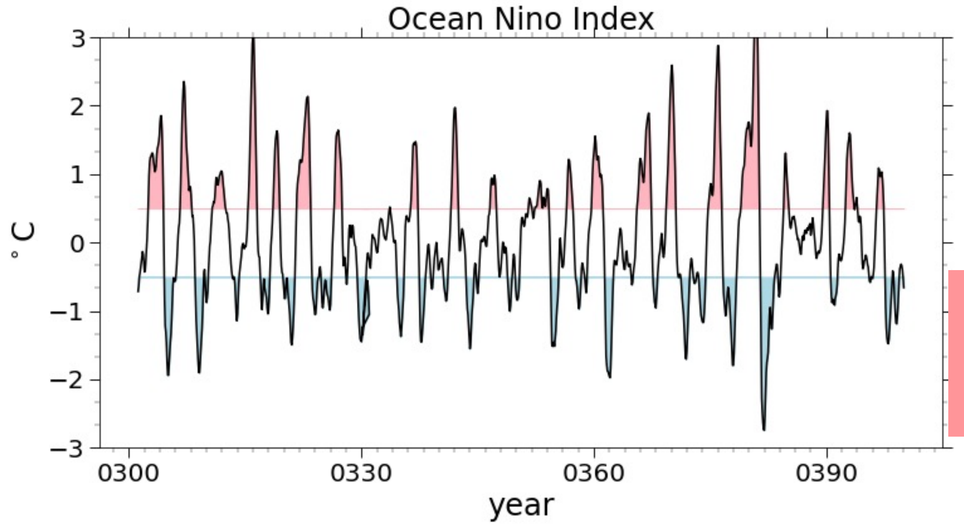
Impact on ENSO



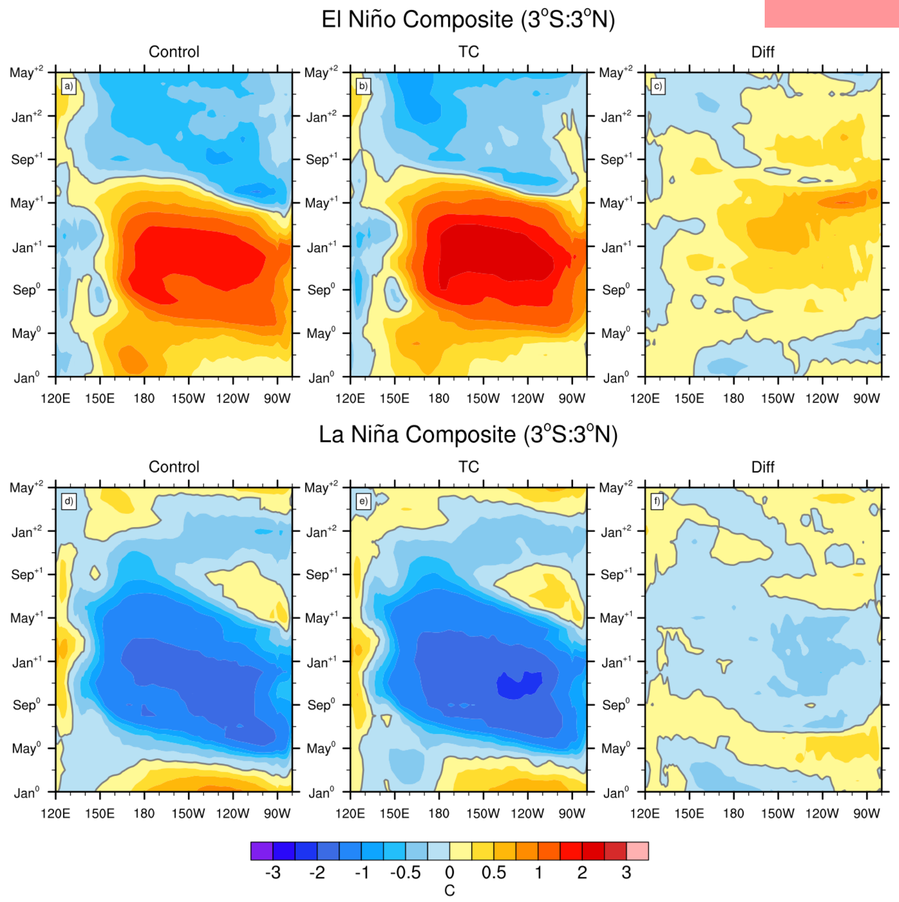
Control



Added TC

More extreme ENSO events?

Enhanced ENSO magnitude



Summary

- We examine the impact of TC wind forcing in a fully coupled climate model by prescribing high-res TC winds into a low-res model
- TC winds can increase the OHC, with an average annual heating rate of 0.03 PW.
- TC winds can impact global SST patterns, leading to changes in surface heat fluxes and precipitations.
- TC winds strengthen the STCs and the meridional ocean heat transport in the Pacific Ocean. The AMOC weakens due to anomalous buoyancy gain in the NA subpolar gyre.
- TC winds may increase the magnitude of El Nino events.

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